EXTRACTS

FROM THE

DETAILED REPORT

ON

YOUNGSTOWN IRRIGATION EXPERIMENTS

Edited by

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ACKNOWLEDGEMENTS

The information gathered together here represents the planning, execution, and summarizing of extensive research extending over the period 1950 to 1963. Many individuals have been involved and several institutions. We wish to acknowledge their contribution here.

Dr. O. S. Longman, Dr. J. D. Newton, W. L. Jacobson, and W. E. Bowser were influential in originating the idea of research on the problem of irrigating the hardpan soils of the proposed William Pearce Project. The late Dr. N.H. Grace, as Director of the Research Council, took a keen interest in the research program.

For the initial experiments at Youngstown both the Lethbridge Research Station and the University Soil Science Department established test plots. The former were planned by W. L. Jacobson and K. K. Krogman while the initial University experiments were designed by Dr. J. D. Newton, Dr. J. A. Toogood, and A. L. Mathieu. Messrs. Krogman and Mathieu carried the major load of the direction of the plot work and the development of the experimental program from 1952 onwards. Mr. Krogman remained in charge of the Lethbridge Station's part of the program until it terminated in 1957 and Dr. Mathieu in charge of the University's part until his departure for Tunisia in 1960. Both of these men had the friendly assistance from neighbors Clinton Zinn and Wally Armstrong and the able help over the years of several undergraduate students. Among the latter were: G. H. Anderson, J. A. Goodbrand, W. Haessel, J. Jan, P. Jenson, F. Kannapinn, W. Lund, R. J. Miller, W. K. Opheim, H. Puffer, G. J. Tajcnar, R. L. Thomas, and H. Williams.

We are particularly indebted to Senior students Anderson and Lund who carried the full burden of plot management in 1961 and 1962.

The research program of the Lethbridge Research Station reported here

was summarized by K. K. Krogman. The University's research program was summarized by Messrs. Mathieu, Tajcnar, Lund, and Toogood. Some of the data herein are taken directly from the M. Sc. thesis of A. L. Mathieu and a few details from his Ph. D. thesis. Some of the data on salinity of soils and water were obtained from the P. F. R. A. laboratory at Vauxhall and the help there of R. A. Milne and his staff is gratefully acknowledged.

A major undertaking, relating to the whole Wm. Pearce Project, and affecting the application of conclusions reached in the research program, was the soil survey of a major portion of the potentially irrigable area. This was done by the Alberta Soil Survey and we are indebted to W. E. Bowser, R. A. Milne, A. Kjearsgaard, F. Schroer, and T. W. Peters for the report on the soils of the area.

INTRODUCTION

The William Pearce Project, also often referred to as the Red Deer Irrigation Project, has been on the drafting boards for several decades. Following World War II there was an increasing amount of pressure placed on the provincial government to begin development of the scheme. By 1950 soil survey groups of the Canada Department of Agriculture and the Research Council of Alberta were actively engaged in classifying the soils of the area. Under the chairmanship of Dr. O. S. Longman, a committee with broad representation from provincial, federal and university agencies, was meeting to discuss various aspects of the project, - economics, soils, meteorology, engineering, power, land development, recreation, etc. Early reports from the soil survey groups indicated that the soils were not all well suited to irrigation and that in fact a large proportion of them might even be

unfit for development. A summary of information obtained in the soil survey of the project area, provided by W. E. Bowser, is given in the following table.

Soils of the Wm. Pearce Project

Sub Group	Acreage	Suitability for irrigation, apart from topography
Rego	35,900	75% poor, balance fair to fairly good
Orthic	105,600	40% poor to fair, 53% fair to fairly good, 7% good
Solonetz	22,500	All poor or non-irrigable
Solodized Solonetz	202,900*	76% poor, balance poor to fair
Solod	8,000	Fair to fairly good
	374,900	54% poor, 24% poor to fair, 22% fair to good

* The major problem soil is Hemaruka loam, with an acreage of 140,000, which is 37% of the surveyed area.

The hardpan or Bt horizon of the Hemaruka soil is the basic difficulty to be overcome if these soils are to be successfully irrigated.

Subsequent discussions and debate culminated in the following letter from Dr. J. D. Newton, Head of the Soil Science Department, to Dr. N. H. Grace, Director of the Alberta Research Council:

December 20th, 1951.

Dr. N. H. Grace, Chairman,
Research Committee,
Department of Agriculture,
Research Council of Alberta.

Dear Dr. Grace:

Soil surveys have shown that much of the area of the proposed Red Deer irrigation project has hardpan (solonetzic) soils. In fact over half of the proposed irrigation area of about 400,000 acres (under the ditch) consists of this kind of soil. Much of it is severely solonized and has a "tough" hardpan and a somewhat salty subsoil. Soils of this extreme character have not been irrigated in Alberta up to the present time, and we have been unable to ascertain that such soils have been successfully irrigated elsewhere. We therefore recommend that before millions of dollars are spent in bringing water to these soils they should be thoroughly investigated.

To this end we recommend that a comprehensive plot and laboratory investigation of these soils be carried out. The object would be, (1) to study the physical and chemical properties of these soils as affected by irrigation and cropping, and (2) to find out if treatment with chemicals such as gypsum and sulphur would improve their physical properties, and (3) to determine whether crops can be successfully grown on these soils under irrigation.

The physical properties of the soil, and especially the physical properties of the hardpan, determine the penetration of water. Physical properties also determine moisture holding capacity. If the soil will not "take" sufficient water it will not be satisfactory for irrigation. Therefore in this investigation the physical properties of the original soil and changes in these properties brought about by irrigation and cropping with grain and deep rooted crops such an alfalfa or sweet clover should be especially

studied. The Department of Soils has some special equipment for the study of physical properties, and one member of the staff, Dr. Toogood, is a specialist in soil physics.

A good deal of research work has already been done and published by the Department of Soils on the chemical properties of Alberta's hardpan or solonetzic soils. These soils are rather salty and the kinds and quantities of salts present have been determined, as well as the base exchange properties of the soils. Changes in salt content and base exchange properties brought about by irrigation and cropping should be studied, and the Department is well equipped to carry on these investigations.

The Department of Soils is equipped to carry on special phases of this investigation which can hardly be undertaken by any other existing agency in this province. However, if any field plot investigations are undertaken in this area by the Dominion Department of Agriculture, care will be taken to correlate the work and avoid duplication.

The proposed investigation involving field plot experiments in the Red Deer irrigation district and artificial watering of plots, as well as laboratory investigations can hardly be carried on for less than $3500. per year, and the work should be carried on for three years probably. We are therefore asking the Research Committee to recommend a grant of $3500. in 1952-53 for this research. A tabulated statement of possible costs is attached.

Yours very truly,

J. D. Newton,
Professor of Soils

The funds requested were granted and work began early in 1952. Drs. Newton and Toogood met with Messrs. W. L. Jacobson, K. K. Krogman, and L. G. Sonmor at Lethbridge. It was agreed that experiments would be carried on jointly, with the Lethbridge staff studying consumptive use while the University would concentrate on physical and chemical aspects of the problem.

The site selected was in the south-east quarter of 28-28-10-W4 beside a P. F. R. A. stock watering dam. The soil survey staff and the

research personnel involved agreed that this site met the following requirements:

(1) The soils were typical of the solonetzic soils which had been mapped in the survey and whose irrigability was questioned.

(2) Topography was reasonably suitable and stoniness was no problem.

(3) An adequate supply of water for irrigation was at hand.

The site was selected in May, 1952. Messrs. Krogman, Mathieu and Toogood laid out the initial experimental plots and plowed and worked up the land in time for a late seeding of barley. Irrigation was first applied on July 16, 1952.

HISTORY OF THE EXPERIMENTS

As pointed out in the Introduction the experiments began in 1952. The major events in the operation of the plots throughout their ten-year history are enumerated here.

1952 - (1) University's A plots laid out. Soil amendments added. Barley seeded and irrigated.

(2) Lethbridge consumptive use plots set up. Rotation established and rill irrigation started.

(3) Soils of A plots sampled to 4 foot depth.

(4) Detailed soil survey of the plot area completed by Soil Survey staff.

(5) Fences erected, dug-out water reservoir constructed, weather station set up.

(6) Area west of the dam worked up in preparation for expansion of experiments in 1953.

(7) Physical and chemical analyses begun.

1953 - (1) Regular rotation established on A plots.

(2) B plots laid out and seeded to blanket crop of barley. Area fenced. Sprinkler system set up.

(3) Field day, July 15.

(4) Soil management practices of a number of successful farmers, some using irrigation, were checked.

(5) Penetrometer readings begun.

1954 - (1) Research Council deep-drilling rig visited plots and checked depth of till and bed rock to depth of 30 feet.

(2) Field day, July 21.

(3) Small header constructed to harvest plot samples.

(4) Land levelling plots planned by Lethbridge personnel.

1955 - (1) First crop year on land levelling plots.

(2) Some sugar beet seedings attempted on a small scale.

1956 - Regular experiments continued.

1957 - (1) Amendments applied a second time to A plots.

(2) Eroded pit experiment planned.

(3) Severe hail storm on August 11 destroyed 50 to 75 per cent of the crop.

(4) Lethbridge Station terminated their experiments.

1958 - (1) Eroded pit experiment laid out.

(2) Dry land test plots set up on C. Zinn's farm to check on effectiveness of attachment, designed by A. L. Mathieu, for Noble blade weeder.*

(3) Some winter wheat seedings on dry land tried.

1959 - (1) Attempted seedings of crested wheat, tall wheat, and slender wheat grasses on strips of virgin range land and slough bottom.

* Separate report on this study published. See paper by Dr. A. L. Mathieu "Chisel attachments for the blade cultivator", Can. J. Soil Sci. 41: 81-85. 1961.

(2) Land levelling plots seeded down to forage mixtures, north half to be irrigated and south half dry, using recommended species.

(3) Seeded consumptive-use-of-water ranges I, II, III, and IV to crested wheat grass.

1960 - (1) Applied manure, gypsum, sulphur and krilium to A plots.

(2) Carried out survey of adjacent farms to collect data on dry land yields of wheat on fallow 1953-1960.

(3) Interim report presented to Special Areas Investigation Commission. Dated October 13 and prepared by J. A. Toogood.

(4) Range VIII of consumptive-use plots plowed and laid out for C plots, an experiment to test several amendments not included in A plots.

1961 - (1) Began final compilation of data.

(2) A, B, and C plots and land-levelling plots continued.

1962 - (1) Final year of experiments. Crested wheat seeded with grains on all plots.

(2) Camp closed down. Lethbridge property returned to Vauxhall. Research Council property (trailer, tractor, machinery, etc.) moved to University's Ellerslie Farm. Garage sold to C. Zinn.

DISCUSSION OF RESULTS

In examining the data for the Youngstown experiments one should keep in mind the levels of production achieved elsewhere in Alberta on irrigated land. Rotation "U" at the Lethbridge Research Station for example provides some data on irrigated crop yields that can be compared in a general way with the yields on the Hemaruka soils. The following table appears in the report to the Alberta Advisory Fertilizer Committee for 1962.

Crop Yields on Rotation "U"

(Cereals in bushels, hay and sugar beets in tons, per acre)

Crop	Treatment	Fertilized 30-yr. av. 1933-1962	Non-fertilized 52-yr. av. 1911-1962
Barley		80.3	70.2
Oats		110.6	100.7
Alfalfa 1	100 lb. 11-48-0	2.96*	2.26*
Alfalfa 2		2.71*	1.50*
Alfalfa 3	15 tons manure	1.93*	1.21*
Sugar beets	100 lb. 11-48-0	19.20	16.19**
Wheat		58.5	54.3
Alfalfa 1a	100 lb. 11-48-0	3.13	2.52
Alfalfa 2a	15 tons manure	3.78	2.89
Alfalfa 3a		3.38	2.99

* Average yields following revision in 1951

** 40-year average.

It must be admitted at the start that the management of any soil improves with experience. Undoubtedly yields on the Youngstown irrigation plots could have been better in the early years if better techniques had been used. Tilling solonetz and solodized-solonetz soils below or above a critical moisture level for example results in impairment of structure. Soil moisture is vital at seeding time, not only for germination, but to prevent crusting which can occur and seriously reduce emergence. Counteracting such factors as these however in the early years of the experiments there were two or three seasons with above normal rainfall. The yields from the Youngstown plots should therefore be a fairly reliable indication of what a farmer might expect if he were to attempt to irrigate such soils over a period of years.

The A plots

Research program

The plot area was selected and the experimental plots laid out in May, 1952. The area had at one time been cultivated but had been abandoned for many years and had reverted to more or less native cover. After plowing the area was disced, harrowed and the treatments applied.

The objective in this set of plots was to investigate especially the value of certain amendments for improving the irrigability of the soil. It was recognized from the beginning that the soil was extremely variable and a compromise had to be made between number of treatments and number of replications. Coupled with the use of amendments the value of sweet clover as a soil improver needed to be checked. With consideration of all these factors the final design of plots was selected with water to be provided by rill irrigation.

The amendments were selected on the basis of previous research in Alberta and elsewhere. Sulphur was known to have an acidifying effect on soils and it was thought its addition might help improve the structure of the Bt horizon. Krilium had just appeared on the market and appeared to offer promise as a soil conditioner. Gypsum had been used for years as a corrective agent in high sodium soils and it was felt this amendment might improve the Hemaruka soils. Farm yard manure was selected as an amendment because of its well-known beneficial effects on the structure of soils, especially those low in organic matter content.

As an additional treatment in the A plots it was felt desirable to test deep tillage. This meant annual chiselling to a depth of about 16 inches at 4-foot intervals in an effort to break up the hardpan and improve infiltration rates and root growth.

To measure the value of these various treatments it was of course necessary to have an irrigated check plot; to measure the value of the irrigation alone, an unirrigated or dry check plot was included. Yields were measured by sampling a strip 3' x 40' down the centre of each plot. From the beginning it was known that data for several years would be required in order to get reliable averages. This became particularly obvious when weather conditions turned out to be unusually favorable for the first few years of the experiments.

Irrigations had to be frequent and rarely exceeded an inch or two of water at a time because of the extremely slow infiltration rates. There was no noticeable improvement in infiltration rates on any of the plots over the ten-year period. From 1957 to 1962 a single sprinkler application was used immediately after seeding to ensure germination.

Results

The highest single yield of wheat recorded was 45.0 bu./ac. in the manure plots of block C of the 2-year rotation in 1958. In 1956 these same plots averaged 41.9 bu./ac. These are the only figures in the entire tabulation of yields exceeding 40.0 bu./ac. About one-quarter of the yields on irrigated plots are in the 30.0-39.9 range and over one-half of them are in the 20.0-29.9 range. These yields for fertilized and irrigated wheat are not encouraging when compared with the Lethbridge yields of 54.3 and 58.5 bu./ac. referred to above. While the Lethbridge yields occurred in a 10-year rotation including six years of alfalfa there could be no fertility problem at Youngstown because commercial fertilizers were used annually.

The object of the A plots was to test the value of amendments. All those used appeared to have helped to some degree, sulphur increasing average yields of wheat 5.0, krilium 3.2, gypsum 5.9, and manure 8.2 bu./ac.

The costs of the chemicals however would be prohibitive in achieving these relatively small improvements in productivity. Manure was the only practical amendment. Deep cultivation brought a 2.5 bu./ac. increase. The use of sweet clover in rotation with wheat helped to the extent of 4.1 bu./ac. The sweet clover yields were low and even with the best treatment, the manure application, amounted to only 1.2 tons per acre.

The yields of the dry plots were of course much lower than the irrigated plots and compared reasonably well with dry-land yields obtained on adjacent farms. This was checked for the years 1953-60.

One of the major problems emphasized by the data is the extreme soil variability. This is indicated by the varying growth of native vegetation and the crops of barley in 1952, wheat in 1953, and wheat in 1956. The differences in quality of the grain produced is indicated by the wide range of protein content found in samples from blocks B and C in 1960.

The attempt made to correlate the 10-year average wheat yields with original cover is not conclusive. The highest yielding plot was III M, whose original cover was mostly heavy buck brush (S. occidentalis). The soil in these spots was friable, of good structure, and lacked the conspicuous hardpan of adjacent soil profiles. One might ask whether the buck brush was the cause or the result of this desirable soil tilth. A study of other plots, even taking into account that the sample was always a three foot strip along the centre of the plot, shows no conclusive relation between yield and original cover.

The B plots

Research program

To supplement the information provided from the A plots a second area was selected for a more detailed study of cultural management of the Hemaruka soils. The area selected was one on virgin prairie.

The main objectives in the setting up of the B plots were:

(1) To test the value of different tillage methods, namely deep cultivation or ripping to 20" depth at 4-foot intervals, plowing to a depth of 18", chiselling to 8" depth, and normal shallow cultivation.

(2) To test the value of crop rotation and deep-rooted legumes, alfalfa and sweet clover, as agents for opening up the soil and improving irrigability.

(3) To evaluate the adaptability of the sprinkler method of irrigation.

First the whole area was plowed and worked up. A blanket crop of barley was seeded in June, 1953, to serve as an indicator of the uniformity of the whole area. As expected, of course, there was extreme variation. Deep plowing and ripping were done in the fall of 1953 and the plots laid out in the spring of 1954. Each individual plot area measured 10 x 40 feet. Different crops and rotations were used. Recommended rates of fertilization were used each year.

In August of 1956 and 1961 the alfalfa plots were plowed up and worked down preparatory to seeding to wheat the following years.

Results

The variability in the soil was again a conspicuous factor in crop production. The barley crop, planted as a uniformity trial in 1953, received adequate rainfall to produce a good stand where the soil was suitable. There were several spots however where there was no crop and many areas where growth

varied from a few inches in height to as much as two feet.

An annoying aspect of experiments located on such variable soils is the difficulty of distinguishing effect of treatment from effect of soil. Replication is supposed to take care of this but yields for any one of the treatments for any one of the nine years show that there was very little agreement among the four replicates. Statistical analyses of the data nearly always showed no significant differences between treatments whether on irrigated or on dry-land plots. When the data for the nine years are combined however an important conclusion appears to be warranted.

Whether we examine the averages for wheat in rotation or continuous wheat there appears to be no doubt that deep plowing was effective, increasing yields from 23.2 to 32.9 in rotation and from 14.5 to 23.0 in the continuous plot. Oats also profited, yields increasing from 39.5 to 57.7. The sweet clover in rotation likewise grew better on the deep plowing plot, producing 0.4 tons per acre more. The deep cultivation was almost as effective as the plowing.

Three questions immediately arise if we accept the conclusion that deep plowing is desirable. Would the heavy initial cost of a deep plowing operation be economical, coupled with other costs of installing an irrigation system? Are the gains, which appear to be within reach, large enough and the final productivity of the soil high enough, to warrant the time and costs? How often would deep plowing need to be done?

Included in the objectives of the B plots was the hope of finding out if alfalfa would open up the hardpan and result in good yields of wheat. Accordingly 3-year and 4-year stands were plowed under in 1956 and 1961 respectively and seeded to wheat in 1957 and 1962. The crops were poor and certainly not as good as the deep tillage treatments. There is a possibility however that the alfalfa residue had not had time to decompose properly as the wheat crops showed definite deficiency symptoms. The alfalfa should have been

plowed under earlier than it was.

Eroded pit experiment

In 1958 a number of eroded pits in the vicinity of the A plots were cultivated and prepared for a crop in 1959. Eleven chemical amendments were applied and wheat seeded. Water was applied from a portable tank. The experiment was intended as a guide to further tests. Results were as follows.

Average yields of wheat in eroded pit tests, 1959

Chemical Amendment	No. of plots	Yield in bu./ac.
Ca SO_4	4	18.9
Alum	"	16.7
Mn	"	15.7
S	"	12.7
K Cl	"	12.4
Zn SO_4	"	12.2
Coal	"	11.7
Mo	"	11.2
Check	15	11.0
Lime	4	9.4
Cu SO_4	"	7.8
Boron	"	5.6

This exploratory test aimed to check the effectiveness of a number of chemicals in breaking up the hardpan or improving plant growth. Rates of application were high, similar to those used later in the C plots. Even the eroded pits however proved to be variable and replications of given treatments failed to agree closely. In many of the plots crusting was so severe that emergence was prevented and wheat yields thus affected. However the effectiveness of $CaSO_4$ is worthy of note and agrees with the success of gypsum on the A plots. The possibilities of alum and manganese having a desirable effect were of interest. Rates of application were of course totally impractical. It must be realized that the exact nature of the cementing forces in the hardpan layer has yet to be discovered. Most current theories attribute them to a combination of type of clay mineral, organic compounds and suite of cations on the exchange complex. The introduction of humus or humic acids and their beneficial effect on soil aggregation account for the value of manure as a supplement to these soils and explain why coal was used as an amendment.

The C plots

These were a sort of all-out assault on the problem. The treatments coupled every conceivable chemical amendment with liberal applications of a variety of commercial fertilizers. But the stand of wheat on these plots in 1961 showed more variability due to soil than to any of the applied treatments. Differences between replicates were so great that the increases over check cannot be relied on as significant differences. It was hoped that a second crop, in 1962, would add more weight to this experiment and give some conclusive data but the test was ruined by range cattle getting into the plot area.

The land levelling studies

The degree of difficulty in levelling this two-acre area of Hemaruka soil may be gauged by comparing the topographic maps. Added to the fact that the soils in the eroded pits when dry are extremely hard and compact, and would be difficult to pulverize for a smooth levelling job, the uneveness of the topography in such a small area shows that levelling here for flood irrigation would be a painstaking process. There is also the problem that the Ah horizon varies from none at all in the eroded pits to six inches or more in between them. The fact that the pits are not all at the same elevation would make the uniform spreading of the Ah horizon difficult if not impossible. The importance of this Ah horizon however from the fertility point of view and the effect of cutting and filling on crop production are not large. Although a tendency for fill areas to outyield cut areas is indicated, the differences in productivity are not large compared to overall variations. The outstanding feature of the yield data is their wide variability, the green weights of oats in 1955 varying from 0.20 to 5.67 tons per acre and the yields of barley in 1956 varying from 7.8 to 80.8 bu./ac. Obviously the levelling process did not result in a uniform soil.

The University's experiments on the land levelling plots were aimed to gauge the forage-producing potential of this soil under irrigation compared to dry-land production. The recommended mixture of brome, creeping red fescue, orchardgrass and White Dutch clover was seeded in 1959 on the half of the plots to be irrigated and some reseeding was done in 1960. In 1961 at time of sampling brome dominated the mixture with less than ten per cent of the other grasses and clover present. Yields were again extremely variable but averaged 2.4 tons of mature grass hay. The crested wheat, tall wheat, and slender wheatgrass mixture seeded in 1959 on the dry half of the land levelling plot was,

by 1961, almost a pure stand of crested wheat. The yields averaged 0.92 tons per acre, which is estimated at more than double the yield of forage on the adjacent native range land.

The 1962 crop of wheat on the irrigated half of these plots was the eighth year of cropping following the initial land levelling. The yields varied from 17.7 to 48.1 and averaged 30.7 bu./ac. The variability observed in the oat crop of 1955 had not disappeared by 1962 but showed some signs of being reduced. Thus, while green oat yields in 1955 varied from 0.20 to 5.67 tons per acre, a 28-fold spread, the wheat yields of 1962 varied only from 17.7 to 48.1 bu./ac., a 2.7-fold spread. This tendency for stand of crop to become more even on particular plots over the years was also observed on A and B plots.

Report on survey of special farms, 1953

Representations from local Chambers of Commerce and Irrigation Associations to the government made two claims which must be refuted. The first was that a group of successful farmers were, by 1952, already successfully farming the problem Hemaruka soils. A specific list of their names was provided. The survey made by Dr. A. L. Mathieu of the farms referred to showed that only two of the nine farmers were irrigating the Hemaruka soil. One of these irrigated "5-10 acres of pasture land and a garden" while the other irrigated "alternate 20-acre fields each year" and found that the soil became very hard and impervious after irrigation. Claims that the E.I.D. was already successfully irrigating similar soils in the Tilley area must likewise be refuted since soil surveys have shown that the major portion of the soils in the Tilley area are eluviated chernozems and weakly developed solods. Both have much more permeable subsoils and are less saline than the Hemaruka soils.

The second claim which must be examined carefully is the one that the plots were located "on one of the poorest pieces of land in the district"

and not "a true average of the lands to be tested". An examination of the soil survey map of the project area shows that 25 different soil types were recognized in the 374,500 acres mapped. Only 8 of these soil types, with an acreage totalling 79,700 were classified as fair to good irrigation soil, and this did <u>not</u> take topography into account. Of the remaining 294,800 acres the survey mapped 140,000 as Hemaruka loam. This soil type, occupying the large acreage that it does, comprises 37 per cent of the surveyed area, makes up the major portion of the irrigable area, and is at the bottom of the list as far as irrigability is concerned. It was essential that this poorest soil receive attention. Could it be irrigated successfully? Was there any way of overcoming its inherent problem of low permeability and salinity?

As to the particular site chosen one must have confidence in the soil surveyors. These men have travelled over every road allowance in the area, dug and examined the profiles of soils in every section of land, in every township. When soil surveyors agree then that the site selected was typical of the Hemaruka loam soil type occurring in the William Pearce project their word must be accepted. One might argue that a particular soil type covers a range of characteristics and that the site selected was near the bottom of the range as far as irrigability is concerned. As the experiments have demonstrated however the soil is so variable over even an acre or two that it is doubtful if this criticism could be upheld.

<u>The chemical properties of the soils</u>

The chemical analyses of the Youngstown plot soils centred around various aspects of their salinity. Little attention was given to their nutrient content since it was known that lack of fertility was a problem easily overcome. Being in the Brown Soil Zone these soils could be expected to respond under irrigation to applications of nitrogen and phosphorus and in all the tests commercial fertilizers were used at recommended rates to make up for any deficiencies.

The major task, in terms of soil chemistry, was to assess the salinity hazard in the Hemaruka soils. The U. S. D. A. Handbook 60 was the basic reference which guided the analyses and provided criteria for classifying the soils as to the seriousness of their salt problem.

One of the standard tests for salinity is the measurement of the conductivity of an extract from a saturated soil sample. Conductance is measured in terms of millimhos per centimeter and readings are directly related to soluble salt content of the soil. Readings of conductivity are classified in Handbook 60 as follows:

0 - 2	-	Salinity effects mostly negligible
2 - 4	-	Yields of very sensitive crops may be restricted
4 - 8	-	Yields of many crops restricted
8 - 16	-	Only tolerant crops yield satisfactorily
16 -	-	Only a few very tolerant crops yield satisfactorily.

With this scale in mind we may examine the conductivity of the A plot soils. Of 21 surface foot samples only 3 tested less than 2 mmhos. while 10 tested over 4 mmhos. In the second foot of soil 14 out of 21 tested over 4, in the third foot 15 out of 21, and in the fourth foot 18 out of 21. Only one plot out of the 21 could be said to have negligible salinity.

The salinity measurements of the B plot samples were made using an older procedure but results indicate the same salt hazard as in the A plots. Here about 10 per cent of the 80 plots were relatively salt-free.

Krogman and Milne compared the salinity characteristics of three soils: non-irrigated Hemaruka, irrigated Hemaruka, and irrigated Halladay. Their data place the Hemaruka soil in the Handbook 60 category of saline-alkali soils while the Halladay soil, top two feet only, would rate as non-saline and non-alkali. Their study emphasized however that these soils occur in such close

association in the field and the sub-soils are so rich in soluble salts that irrigation would only aggravate the situation by

(1) Moving soluble salts from the Hemaruka to the Halladay, and

(2) Bringing soluble salts up from the subsoil to the surface by evaporation.

The element sodium, when in the cation exchange complex of clay minerals, is particularly injurious to soil structure. It leads to break down of aggregates and to excessive swelling of clays, and hence the calculation of SAR values (sodium adsorption ratio) which relates the amount of sodium present to the other major cations calcium and magnesium. Dr. Mathieu's data show how much worse the Hemaruka soil is, compared to the Echo and Trossachs series, with respect to the relative amounts of sodium.

A detailed analysis of exchangeable cations was carried out in 1952 and 1959. For various reasons the methods of analysis used in the two years were not identical, particularly as they applied to measurement of Ca and Mg. The tendency was to get higher values for these two exchangeable cations in 1952, when the Versene procedure was used, compared to the flame photometer data of 1959. As percentages of the total exchange capacity however, the data for the two years are comparable. The data for the individual replicates show wide variations and no indication that any of the treatments had any effect on the exchange complex. One might have expected exchangeable H to increase where sulphur was added, and Ca where gypsum was added. The figures give no hint of such a change. To remove excess sodium from a soil one must not only apply gypsum (or some other source of calcium) but also provide drainage so the sodium displaced can be flushed out. No drainage was possible on the Youngstown plots so it is perhaps not surprising that there were no marked changes in the exchange complex in this 7-year period.

Water quality

The following observations appear to be warranted relative to quality of water used in the experiments:

(1) The water in the P. F. R. A. dam was similar in quality to that being taken from reservoirs for irrigation in the E. I. D., B. R. D. and S. M. R. D. areas of southern Alberta.

(2) Most waters being used in Alberta have a reasonably low sodium hazard but contain enough salts in solution to be classified as "medium salinity water" by the U. S. D. A. Handbook 60. The Handbook states that such water "can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control".

(3) Using Red Deer river water, water class C 2 S 1, to irrigate soils so high in soluble salts as the Hemaruka series would be inviting trouble unless elaborate means were to be taken to provide leaching.

The physical properties of the soils

There is no doubt that certain physical characteristics are the dominant faults of the Hemaruka soils. What are these characteristics?

(1) Wide variability in texture which results in a wide range in infiltration rates, hydraulic conductivity, structure and moisture holding capacity.

(2) A high percentage of clay and silt in the Bt horizon, associated with and causing the hardpan condition.

(3) While the hydraulic conductivity of the friable Ah horizon is quite satisfactory, that of the Bt horizon is frequently close to zero.

(4) The soils are poorly aggregated, especially in the Bt horizon as indicated by the low total porosities and low mean weight diameters. Also, the stability of aggregation is extremely variable.

(5) Penetrometer studies showed large variation in depth of isoprobes, indicating wide differences in compaction and moisture content of the soils.

Effect of treatments on physical properties

The purpose of adding amendments to the A plot soils was to produce a better soil structure. By measuring the stability of aggregates in 1953 and again in 1959 we hoped to be able to demonstrate some success in this regard. Results were disappointing. In the 1953 analyses the only treatment which had altered mean weight diameter was krilium. This was effective in improving yields but would be impractical because of the high cost of the chemical. It does support the contention however that improvements in structure in this soil will boost productivity.

By 1959 some of the other treatments appear to have borne fruit. Compared to the irrigated check plot the krilium, manure, and sulphur treated areas all had larger stable aggregates. Average yields from these plots was not well correlated however with mean weight diameter as shown in this tabulation:

Treatment	M. W. Diam. '59	Yield '53-'62
K	1.16 mm.	27.0
M	1.11	32.0
S	1.09	28.8
DC	1.06	26.3
G	1.02	29.7
IC	1.00	23.8
Dry	0.82	6.6

Penetrometer studies

Since the hardpan in the problem soils under study was the distinctive feature that we wished to observe and study it was felt necessary to attempt some method of assessing any beneficial effects the treatments might be bringing about. A penetrometer seemed to be a promising device, that is an instrument by means of which the pressure or force needed to force a probe into the soil could be measured. Hardpans are readily detected by such an instrument. A great disadvantage is the pronounced effect of soil moisture content on pressure readings, the tendency being to find low values in moist soils and high values in dry ones.

Dr. A. L. Mathieu, in connection with his M.Sc. program, designed and had built a recording type of penetrometer which made it possible to take penetrometer readings rapidly. This was essential in order to have sufficient replications of measurement to overcome normal variability in soils. It was particularly important here where the soil was so variable to begin with.

Where the isoprobe is from two to four feet below the surface it is likely that no hardpan is present. Variations in the isoprobe curves must also be due to the differences in texture and structure already referred to and to the consequent differences in moisture content. The fluctuations in these isoprobes indicate as well as if not better than any other data gathered concerning these plots the extreme variations in the soil over very short distances.

If any of the treatments had a mellowing effect on the hardpan then isoprobes for these treatments should have been deepened over the period. The June readings show this was the case for the krilium and gypsum treatments but not for the manure treatment. The September readings reverse the picture. In spite of the large number of replications therefore it is difficult to put confidence in the differences portrayed. The September readings were much less

than the June readings only because the soil was dried out, but if this is true it is not clear why the "Dry" plot isoprobes in June were as deep as those for the "Irrigated check" plots.

A few conclusions appear to be justified:

(1) Deep cultivation and deep plowing loosened the soil to a depth of 20 inches and the effect lasted from the time of the operation in 1953 until 1959, at least on the irrigated plots.

(2) Isoprobes in the irrigated plots were about four inches deeper than in the dry plots.

(3) With regard to the alfalfa and crested wheat plots, these perennial crops probably resulted in a drier soil, thus accounting for the shallow isoprobes.

(4) The deep plowing isoprobe average on the irrigated plots is deepest and probably indicates the most effective job of destroying the hardpan in all the Youngstown plots.

<u>Consumptive use studies by Lethbridge Station</u>

(Discussion provided by K. K. Krogman)

The May-to-September precipitation varied considerably from year to year. The totals for 1952, 1955 and 1957 were similar to the 1932-1941 average of 7.64 inches which was recorded at a farm near Youngstown and in line with the figures shown for Hanna. The 1930's are usually considered to have been dry years; thus half of the years of the present study may be considered as normally dry. In 1953, 1954 and 1956, precipitation was considerably higher, but not always favorably distributed over the growing season. Except in 1956 when both evaporation and rainfall were high, evaporation from a free water surface at ground level appeared to be inversely proportional to rainfall.

Although soil type greatly influenced yields, substantial yield responses to irrigation were obtained in all years except 1956, when rainfall was ample and timely and high yields were obtained on the non-irrigated plots. The Halladay

soil series in 1955 and 1956 produced yields of wheat, oats, and barley of 48.0, 97.0 and 59.3 bu./ac. respectively while the Hemaruka soil series produced only 25.1, 59.6 and 31.3 bu./ac. Yields of wheat on the consumptive use plots are in general slightly better than on the University's A plots for the same years. This may be accounted for by a larger proportion of Hemaruka soils in the A plots.

From 2 to 5 irrigations were required on the consumptive use plots during the growing season to produce maximum yields, the number depending on the frequency and amount of rainfall. In the drier years, irrigation water had to be applied as frequently as every 10 days to supply the moisture needs of the crops.

The solod (Halladay soil) produced maximum yields with from 3 to 4 irrigations during a normally dry summer. To attain maximum yields on the solodized-solonetz soil (Hemaruka) 6 or more irrigations during the season were required. Furthermore, even with frequent irrigation, the yields obtained on the Hemaruka soil were not larger than the non-irrigated crop yields on the Halladay soil.

Individual applications ranged from 0.5 to 2.5 inches depending on the predominating soil type on the plot and its dryness before irrigating. Because of the low infiltration rates on most of the plots, irrigation water could not be applied faster than about 0.5 inch per hour. It was found that if this rate of application was exceeded, excessive ponding would occur. Also, excessive water erosion tended to occur if irrigating streams were too large. Slopes greater than one per cent appeared critical in this respect. The maximum yields of cereals were satisfactorily high but the yields of forage crops, particularly the pasture mixture were low. Although the poor yields of forage crops were likely due to low fertility and adverse physical conditions of the

soil, there was little or no fertilizer response. Of all of the crops in the study, oats and barley appeared to respond the most to fertilizer, particularly at the higher rates of irrigation.

Consumptive use of water for the growing season increased with increasing levels of irrigation. At maximum yields, consumptive use varied from 13 to 20 inches and averaged between 15 and 16 inches. This is about 2 inches lower than the consumptive use data for the same crops at Vauxhall and Taber in the same years. Also the consumptive use of water by alfalfa was about 4 inches less at Youngstown than that reported for the Upper Kootenay River Valley in British Columbia. The water requirements of crops grown at Youngstown were lower than in Southern Alberta or South-Eastern British Columbia, probably because of shorter growing seasons and somewhat lower evaporative power of the atmosphere.

CONCLUSIONS

1. No treatment was discovered, chemical or physical, which would convert the Hemaruka loam soils to a friable, fertile, irrigation soil.
2. The most promising practical treatments for improving these soils were deep plowing and the application of manure. The practicality of deep plowing would hinge on the economics of the situation.
3. There is practically no internal drainage in these soils and infiltration rates and hydraulic conductivity are too low by present standards for satisfactory irrigation. Applications of small amounts of water would be required too frequently for easy irrigation.
4. Salinity would be a serious hazard if any attempt was made to irrigate these soils.
5. The soils are extremely variable over very short distances resulting

in lack of uniformity of crop stands and variations in height, in yield, and in quality.

In brief, the Hemaruka soils of the Wm. Pearce scheme are unsuitable for irrigation in the foreseeable future. The soil survey report indicates that other soils in the irrigable area closely resemble the Hemaruka. The conclusions respecting the Hemaruka soils apply in lesser degree to them. Still other soils, while suitable for irrigation, occur in such small areas and in such intimate association with Hemaruka that they must also be ruled out. When these factors are considered, and in addition topography, availability of water, surface drainage, and salinity, it is evident that larger areas of good irrigable soils in the Wm. Pearce project are few and far between. The time has not yet arrived when we should spend millions of dollars bringing water to these few areas for purposes of irrigation.